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Device and method for cryogenically separating a gas mixture

The present invention relates to a unit and to a method of separating a gas mixture by cryogenic distillation.

For a very long time, as described in "Cryogenic Engineering" by Hausen and Linde, pp. 457-461, air gas separation units use turbines with lubricated bearings, these bearings being axial or radial. To produce refrigeration, the turbines expand air or nitrogen with the production of external work, the expansion being of the isotropic type apart from irreversibilities.

However, turbines with lubricated bearings, for example those lubricated with oil, have two major drawbacks.

Firstly, there is a risk of the process gas being contaminated with oil should the sealing system along the shaft fail. Such a contamination results in oil migrating into the various items of equipment of the unit (exchangers, pipes, distillation columns, reboiler), the oil possibly tending to concentrate near the main reboiler in the presence of relatively pure oxygen. This could be the cause of a major explosion in the air gas separation unit.

Secondly, it is thus necessary for economic reasons to install the turbine close to the floor in order to minimize the distances from the oil tank; this constraint is not specific to air gas separation plants but may also apply to gas (H_2, He, CH_4, etc.) liquifiers or to other gas separation (H_2/CO, etc.) units.

The object of the invention is to dispense with lubricated bearings for the expansion turbines of units for separating gas mixtures by cryogenic distillation by expanding the gas mixture to be separated in a

turbine on bearings (steel or ceramic ball bearings or roller bearings), these bearings possibly being periodically greased but not being oiled.

One subject of the invention is a unit for separating gas by cryogenic distillation, comprising a system of columns, means for sending a gas to be separated to one column of the column system, means for withdrawing at least one product from the column system, means for sending a gas of the unit, possibly at least one portion of the gas mixture to be separated, into a turbine with bearings, and means for sending at least one portion of the gas expanded in the turbine to one column of the column system if the expanded gas constitutes at least one portion of the gas mixture to be separated, characterized in that the bearings of the turbine are rolling bearings.

Optionally:

- the turbine has unoiled bearings;
- the turbine has unlubricated bearings;
- the gas to be separated contains oxygen and/or nitrogen and/or hydrogen and/or methane and/or carbon monoxide as main components;
- the expanded gas is air, nitrogen or hydrogen,
- the turbine is installed at least one meter above the floor, preferably at least two meters above the floor or even at least five meters above the floor;
- the turbine is braked by a brake booster, possibly of the centrifugal type, placed on the same shaft as the turbine, all the bearings of this common shaft being unlubricated;
- all the bearings of the common shaft are of the rolling bearing type;
- the turbine is braked by a brake generator whose bearings are unlubricated; and
- the bearings of the brake generator are of the magnetic type.

Another subject of the invention is a method of separating a gas mixture by cryogenic distillation, in which a gas mixture to be separated is sent to a column of a column system, at least one product is withdrawn from the column system, at least one portion of a gas of the unit, possibly at least one portion of the gas mixture to be separated, is sent into a turbine with bearings, characterized in that the bearings of the turbine are rolling bearings.

Preferably, the turbine is braked by a brake generator whose bearings are unlubricated and the brake generator is driven at the same speed as the turbine.

The invention will be described in greater detail with reference to the figures, which show air separation units according to the invention.

Figure 1 shows a cryogenic distillation air separation unit in which:

- an air stream 1 is compressed to the medium pressure in a compressor 3 and is then purified in a purification unit 5, which may be of any known type. The air is then divided into two fractions 21, 23. The fraction 21 is cooled on flowing through the exchange line 7 and is sent to the bottom of the medium-pressure column 13 in gaseous form;
- the remainder of the air 23 is boosted in a booster 9, cooled in a chiller 19 and sent to the exchange line 7 where it is partially cooled before being sent to the blowing turbine 11. This turbine may be a turbine on bearings (steel or ceramic ball or roller bearings);
- the turbine 11 is mounted at least one meter above the floor, preferably at least two meters above the floor or even at least five meters above the floor;
- the turbine 11 is on the same shaft as the booster 9. The booster 9 is preferably of the centrifugal type, having unlubricated bearings.

Preferably, all the bearings of the shaft are rolling bearings;

- alternatively, the booster may be replaced with a generator, again with unlubricated bearings;
- the air expanded in the turbine 11 is sent into a low-pressure column 15 with a minaret;
- a rich-liquid stream 25, a lower lean-liquid stream 27 and an upper lean-liquid stream 29 are sent from the medium-pressure column 13 to the low-pressure column 15. A purge stream is withdrawn from the condenser-reboiler 17 that connects the two columns; and
- pure nitrogen 31 is withdrawn from the top of the minaret, waste nitrogen 33 is withdrawn from the bottom of the minaret and gaseous oxygen 35 is withdrawn from the bottom of the low-pressure column. These three streams are warmed in the exchange line 7. Part of the waste nitrogen is used for regeneration after a warming step.

Figure 2 shows a cryogenic distillation air separation unit with an air cycle, in which:

- an air stream 1 is compressed to the medium-pressure in a compressor 3 and then purified in a purification unit 5, which may be of any known type. The air is boosted in a booster 9, cooled in a cooler (not shown) and sent to the exchange line 7 where it is partially cooled before being sent in part to a Claude turbine 11. This turbine is a turbine on bearings (steel or ceramic ball or roller bearings);
- the turbine 11 is mounted at least one meter above the floor, preferably at least two meters above the floor or even at least five meters above the floor;
- the turbine 11 may be coupled to the booster 9;
- the air expanded in the turbine 11 is partly sent to the medium-pressure column 13 and partly recycled (stream 43) to the booster 9. In the variant embodiment with no cycle, all the air expanded in the turbine 11 is sent to the medium-pressure column;

- a rich-liquid stream 25, a lower lean-liquid stream 27 and an upper lean-liquid stream 29 are sent from the medium-pressure column 13 to the low-pressure column 15. A purge stream is withdrawn from the condenser-reboiler 17 connecting the two columns;

- pure nitrogen 31 is withdrawn from the top of the minaret, waste nitrogen 33 is withdrawn from the bottom of the minaret and gaseous oxygen 35 is withdrawn from the bottom of the low-pressure column. These three streams are warmed in the exchange line 7. Part of the waste nitrogen serves for regeneration after a warming step; and

- the unit produces liquid nitrogen 39 at the top of the medium-pressure column and liquid oxygen 41 at the bottom of the low-pressure column.

Figure 3 shows a cryogenic distillation air separation unit in which:

- an air stream 1 is compressed to the medium-pressure in a compressor 3 and then purified in a purification unit 5, which may be of any known type. The air is cooled on flowing through the exchange line 7 and is sent to the bottom of the medium-pressure column 13 in gaseous form;

- a rich-liquid stream 25, a lower lean-liquid stream 27 and an upper lean-liquid stream 29 are sent from the medium-pressure column 13 to the low-pressure column 15. A purge stream is withdrawn from the condenser-reboiler 17 that connects the two columns; and

- pure nitrogen 31 is withdrawn from the top of the minaret, waste nitrogen 33 is withdrawn from the bottom of the minaret and gaseous oxygen 35 is withdrawn from the bottom of the low-pressure column. These three streams are warmed in the exchange line 7. Part of the waste nitrogen is used for regeneration after a warming step;

- medium-pressure nitrogen 45 is partly warmed in the exchange line before being expanded in the turbine

11. This turbine is a turbine on bearings (steel or ceramic ball or roller bearings). The turbine 11 is mounted at least one meter above the floor, preferably at least two meters or even at least five meters above the floor. The expanded nitrogen is mixed with the waste nitrogen 33; and

- alternatively, if the low-pressure column 15 operates at a sufficiently high pressure, it is possible to expand a stream of low-pressure nitrogen in the turbine.

It will be readily understood that the units in question may comprise any possible combination of Claude turbines, blowing turbines and nitrogen turbines, provided that at least one of these turbines is a turbine on bearings (steel or ceramic ball or roller bearings).

The invention is obviously not limited to processes using a column with a minaret. It applies to any type of air separation method using an expansion turbine, including pumped methods.